Federal Aid in Wildlife Restoration Grant W-163-R-1

Annual interim report, March 1, 2019

Evaluating carnivore harvest as a tool for increasing elk calf survival and recruitment

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State: Montana
Agencies: Fish, Wildlife & Parks and Montana State University
Grant: Carnivore Management and Elk Recruitment
Grant #: W-163-R-1
Time Period: 1 January, 2018 – 28 February, 2019

Executive Summary

The purpose of this project is to evaluate the effects of carnivore harvest management on carnivore population abundance and elk calf survival. In 2012, Montana Fish, Wildlife and Parks implemented mountain lion harvest regulations designed to moderately reduce mountain lion population abundance and increase elk calf survival in portions of west-central Montana. We applied a before-after-control treatment approach to estimate mountain lion population abundance in a treatment (Bitterroot) and control (Clark Fork) area before and 4-years after the harvest regulations were implemented. During 2018-2019, we completed our estimate of mountain lion population abundance in the Clark Fork control area. We estimated a population abundance of 72 animals (90% CI = 47, 105) within the Clark Fork study area, corresponding to a density of approximately 2.1 mountain/100 km^2 (90% CI = 1.4/100 km^2, 3.1/100 km^2). We found that mountain lion population abundance in the control area was similar in December 2013 and December 2017, suggesting that the management objective to maintain stable mountain lion populations in the control area was achieved. During 2018-2019, we also completed the final field efforts and analyses evaluating changes in the annual rates of elk calf survival and cause-specific mortality in the Bitterroot treatment area before, during, and 4-years after the period of liberalized carnivore harvest management (treatment). We compiled and compared data on calf survival and cause specific mortality collected from the before, during, and after treatment periods. We found estimates of both summer and winter survival were lowest before liberalized carnivore harvest management, highest during the treatment, and at intermediate levels 4 years after the harvest treatment. Average summer survival rates were 0.46 (95% CI = 0.36-0.58) in the pre-treatment era, 0.67 (0.56-0.80) in the during-treatment era, and 0.57 (0.49-0.67) in the post-treatment era. Average winter survival rates were 0.74 (0.63-0.86) in the pre-treatment era, 0.93 (0.85-1.00) in the during treatment era, and 0.77 (0.71-0.85) in the post-treatment era. During 2019-2020, we will complete final analyses, reports, and manuscripts describing effects of carnivore harvest management on carnivore population abundance and elk calf recruitment in west-central Montana.

Project Background

Elk are an iconic species throughout the western United States and play a large role across ecological (Kauffman et al. 2010), social (Haggerty and Travis 2006) and economic (U. S. Department of the Interior 2011) landscapes. However, since the early 2000's, declines in elk numbers and recruitment in some parts of the western United States resulted in concerns that the recovery of large carnivores such as wolves (*Canis lupus*), mountain lions (*Puma concolor*) and grizzly bears (*Ursus arctos*) has affected elk populations (Bunnell et al. 2002, Cook et al. 2013). Thus, wildlife managers are increasingly focused on understanding and managing the effects of predation on elk populations. Carnivore recovery is important to elk populations because predation may be a proximate limiting and regulating factor for many elk populations (Messier 1994, Hebblewhite et al. 2002. Garrott et al. 2008, Andren and Liberg 2015). In addition to carnivore recovery, changing elk harvest management prescriptions, shifts in land use, and changing habitat and climatic conditions all contribute to a complex suite of variables with the potential to affect elk population dynamics. Because of this complexity, understanding the effects of predation on elk population dynamics is difficult, and determining appropriate management actions is challenging.

To detect and respond to fluctuations in wildlife populations, managers require information on the factors that influence population dynamics. Survival of prime-aged females and recruitment can both have strong impacts on a population's trajectory (Gaillard et al. 1998, 2000; Eacker et al. 2016). However, while adult female survival is often high and relatively stable (Nelson and Peek 1982, Garrott et al. 2003), juvenile survival tends to be highly variable and consequently, may be a more common driver of ungulate population dynamics (Raithel 2007, Harris et al. 2008). Recruitment, which incorporates fecundity and juvenile survival to age l, represents an important demographic parameter that wildlife managers often use to track trends in population growth rates (DeCesare et al. 2012). Although direct assessments of juvenile survival using marked animals offers the most accurate and informative measure of recruitment, such data are difficult and expensive to collect and may not be a feasible option. Age ratios (i.e., number of juveniles per 100 adult females) are a less-expensive and less-time-intensive alternative that provide an index of recruitment that is often used by managers to monitor populations (Harris et al. 2008). Such extensive spatio-temporal data sets offer the potential for monitoring changes in recruitment and for assessing long-term trends in populations (Harris et al. 2008, DeCesare et al. 2012).

In west-central Montana, MFWP administrative Region 2 supports a healthy black bear population, and the numbers and geographic ranges of wolves, mountain lions, and grizzly bears have expanded during the past 10 years. Hunting districts in three watersheds with high carnivore densities have experienced declining trends in elk numbers and recruitment and are currently below elk population objectives. Mountain lion predation and, to a lesser degree, wolf predation, have been documented as important sources of elk calf mortality in this region (Eacker et al. 2016). In an effort to reduce predation on elk in areas with high carnivore densities and declining elk numbers, wildlife managers have applied integrated carnivore-ungulate management strategies over the past 5 years. In conjunction with reduced or eliminated antlerless elk harvest throughout most of the region, carnivore harvest quotas have been increased in an attempt to reduce wolf and mountain lion populations.

When wolf management returned to the State of Montana and hunting resumed in 2011, MFWP liberalized wolf hunting regulations for each of the following 3 years. These changes included adding a trapping season, removing the state-wide quota, extending the season, and increasing bag limits for individual hunters. Additionally, in February 2012, a mountain lion harvest management prescription that increased harvest levels, particularly of female mountain lions, was applied in efforts to reduce predation effects on elk in the western portion of MFWP Region 2, while still conserving mountain lion populations and providing the desired mountain lion hunting opportunity. The prescribed mountain lion harvest management regulations were designed to reduce mountain lion density by 30% over a period of 3 years across approximately 60% of the region and to manage mountain lions for stability, generally at current levels, across the remaining 40% of the region.

Although these steps were implemented to reduce predation on ungulate prey species, there is uncertainty over the ability of liberalized carnivore harvest management prescriptions to achieve harvest levels that will affect carnivore densities at the landscape level. Furthermore, reducing carnivore densities may or may not result in increasing elk calf survival and recruitment because the degree to which predation by each carnivore species is compensated for by changes in losses to other biotic and abiotic mortality factors is unknown. As a result, the effectiveness of carnivore harvest as a tool for increasing elk recruitment and population size is unknown and has not been evaluated.

These recent changes in wolf and mountain lion management in west-central Montana provide a unique opportunity to build on a recently completed project and conduct a robust, multi-scale Before-After-Control-Impact evaluation of the effects of carnivore management on carnivore population density and elk calf survival and recruitment. During 2012 and 2103, we estimated pre-treatment mountain lion density in an area managed for mountain lion reduction (south Bitterroot area) and an area managed for stability (upper Clark Fork area). To assess the effects of mountain lion harvest management on mountain lion population density, we are comparing mountain lion densities in these treatment and control areas before and after 4-years of increasing mountain lion harvest quotas in the treatment area.

To evaluate the effects of carnivore management on elk calf survival and recruitment more broadly, we are conducting a regional evaluation of elk recruitment ratios and a focused evaluation of elk calf survival in the south Bitterroot study area to detect changes in the rate of wolf and mountain lion caused calf mortality. At the regional scale, we will use age-ratio data collected during annual spring surveys to evaluate changes in elk recruitment during different carnivore population and management regimes. This will allow us to broadly evaluate factors affecting recruitment over an extended period of time. On a finer scale, we will compare baseline data on rates of elk calf survival and cause-specific mortality collected before and after 4 years of adapted carnivore management to determine if rates of predation by mountain lions, wolves, or both decreased, and if rates of calf survival and recruitment increased. The baseline elk calf survival and cause-specific mortality rate data were collected as part of a project conducted in the south Bitterroot area during 2011-2014. Building from these efforts, the purpose of this project is to evaluate elk calf survival and cause-specific mortality, as well as carnivore densities, to assess the effect of carnivore harvest management prescriptions on carnivore densities and elk calf survival.

Location

Elk calf survival and mountain lion population estimation is focused primarily within Ravalli County, Montana. Portions of this project also occur in Mineral, Missoula, Granite, Deer Lodge, and Powell Counties.

Study Objectives (2018-2019)

For the 2018-2019 season of this study, the primary objectives were:

1. Complete the second and final year of elk calf survival monitoring in the south Bitterroot area and evaluate the effects of carnivore management on calf survival and cause-specific mortality.

2. Estimate the 2017-2018 mountain lion population size in the upper Clark Fork watershed.
3. Evaluate the effects of wolf harvest management regulations on wolf harvest and population density.

Objective #1: Elk calf survival and cause-specific mortality monitoring

To evaluate the effects of carnivore management on elk calf recruitment, we are estimating rates of survival and cause-specific mortality for elk calves in the south Bitterroot area. The 3,350 km^2 southern Bitterroot valley study area, located in west-central Montana, includes the drainages of the East Fork and the West Fork of the Bitterroot watershed. The East Fork and the West Fork, hunting districts HD 270 and HD 250 respectively, are home to the two elk populations that are the focus of this study. Additionally, the East Fork population has a migratory segment with a summer range in the Big Hole Valley (HD 334, Proffitt et al. 2015*a*).

The East Fork study area encompasses 1,719 km^2 and has an elevational range of 1,100-2,800 m. Portions of the East Fork are heavily roaded, and the area is 18% private land. In comparison to the West Fork, the East Fork consists of more modest terrain, and is characterized by agricultural uses and open grasslands which give way to timbered slopes, sub-alpine, and alpine terrain. The West Fork study area encompasses 1,437 km^2 and has an elevational range of 1,200-3000 m. The West Fork is comprised mostly of public land (95%), with high road accessibility at lower elevations and fewer roads at higher elevations. The West Fork is characterized by heavily forested areas and lower riparian grasslands, and alpine terrain at higher elevations.

To understand changes in the annual rates of elk calf survival and cause-specific mortality in the Bitterroot study area before, during, and 4-years after the period of liberalized carnivore harvest management (treatment), we compiled and compared data on calf survival and cause of death collected from the before, during, and after treatment periods. We considered calves radio-tagged in 2011-2012 and monitored in 2011-2013 as having occurred in the pre-treatment era, as these data were collected entirely before or just a few months after the period of liberalized carnivore harvest management. We considered calves radio-tagged in 2013 and monitored from 2013-2014 as having occurred in the during-treatment period, as these data overlapped entirely with the period of liberalized carnivore harvest management. We radio-tagged calves in 2016 and 2017 and monitored these calves during 2016-2018 to estimate post-treatment calf survival rate and assign cause of death. We compared survival and cause-specific mortality across the three treatment eras to understand changes in the survival and cause-specific mortality of elk calves prior to, during, and several years after the period of liberalized carnivore harvest management.

1.1 Elk calf capture and sampling

During all three treatment eras, we captured neonate elk calves during an approximately 2-week period near the end of May and first week of June each year following approved animal care protocols (MSU IACUC#2016-06, UM IACUC# 027-11MHWB-042611). We used ground and helicopter crews to search for female elk that showed signs of having recently given birth. Ground crews attempted to locate neonates by watching for behavioral indications from adult females and/or by searching areas on foot. Helicopter crews attempted to spot neonates from the air.

From 2011-2012, each captured calf was outfitted with an ATS (model 3430, Advanced Telemetry Systems Inc., Isanti, MN) VHF ear-tag radio-transmitter weighing 23 g. After significant amounts of tag-loss in 2011-2012, calves in all other years of the study were outfitted with TW-5 VHF ear-tag radio transmitters (Biotrack, Wareham, Dorset, United Kingdom) that weighed 1.8 g. We recorded the sex, weight (kg), and morphometric measurements to estimate calf age. We collected ear punch tissue samples from each calf for potential future identification during mortality investigations.

Figure 1.1 *Hobbled and blindfolded neonatal elk calf. Note ear-tag radio transmitter in right ear.*

To increase our sample size of marked calves entering the winter monitoring period, we captured and ear-tagged an additional sample of 6-month-old calves each year from November to January. We captured 6-month-old calves using a combination of helicopter darting and net-gunning. We fit each calf with a radio transmitter as previously described and recorded the sex of each calf.

During the two pre-treatment years, we radio-tagged 142 calves in the spring and 60 calves at the start of winter (n = 202). In the during-treatment year, we radio-tagged 84 calves in the spring and added no calves at the start of winter (n = 84). During the two post-treatment years, we radio-tagged 183 calves in the spring and 65 calves at the start of winter (n = 248). The total sample size for all three treatment eras was 534 radio-tagged elk calves. We radio-tagged more calves in the East Fork than the West Fork during all treatment eras and maintained a small sample of calves tagged in the Big Hole Valley throughout the study (n = 16, 13, and 31 in the pre-, during, and post-treatment eras, respectively).

Calf survival and cause-specific mortality monitoring

Using a combination of ground and aerial telemetry, we monitored the telemetry signals of calves to determine survival status from the day after capture to 30 May of the following year. We monitored each surviving calf every day from its date of capture to 31 August and 3 to 4 times per week thereafter. We used aerial telemetry from fixed-wing aircraft to obtain weekly locations of each calf from date of capture through 31 August. We did not locate calves from 31 August to the end of November to avoid disturbing elk and hunters during hunting seasons. After hunting seasons ended near the end of November, we located calves monthly until 30 May.

We recorded 19,323 observations in the pre-treatment era (n = 15,708 live, 75 = dead, and 3,540 = not heard), 20,644 observations in the during-treatment era (n = 12,076 live, 35 = dead, and 8,533 = not heard), and 25,185 observations in the post-treatment era (n = 19,419 live, 87 = dead, 5,679 = not heard). We obtained 1,834 estimated calf locations in the pre-treatment era, 919 in the during-treatment era, and 1,514 locations in the post-treatment era.

When we detected a radio signal that was in mortality mode, we used telemetry to locate the radio-tag and then performed a mortality investigation. We used characteristics such as consumption pattern, location and presence of claw marks, location and presence of subcutaneous hemorrhaging, width and presence of bite marks, and general characteristics of the kill site to assign causation to each mortality event. During all years of data collection, we submitted carnivore scat and hair collected during mortality investigations for DNA analysis to determine predator species identity. For the two years of post-treatment data collection, we also swabbed areas that were likely to contain predator saliva, such as sites of subcutaneous hemorrhaging, for DNA analysis to determine predator species identity. We delivered all saliva, hair, and scat samples to the USFS Rocky Mountain Research Station (Missoula, MT) for analysis. Using inferences from our mortality investigations and the results of the DNA-based predator identification, we classified each mortality source as mountain lion, wolf, black bear, unknown predator, non-predation, or unknown cause. Data for each calf that left the study area or whose ear-tag malfunctioned or became detached (e.g., while crossing under a fence) were right censored one day after the calf was last known to be alive.

Figure 1.2 *Cache pile consisting of grass and twigs covering an elk calf carcass.*

Table 1.1. *Number of calves that died from black bear predation, mountain lion predation, wolf predation, non-predation, unknown predator, and unknown cause, by elk herd and treatment era, in the upper Bitterroot Valley, Montana, USA, during pre-treatment, during-treatment, and post-treatment eras.*

Herd	Cause of mortality	Pre-	During-	Post-	Total
East Fork	Mountain lion	11	7	13	31
	Non-predation	3	1	9	13
	Black bear	6	1	1	8
	Wolf	3	0	3	6
	Unknown predator	3	3	3	9
	Unknown cause	13	7	28	48
	Other	2	1	0	3
West Fork	Mountain lion	16	6	6	28
	Non-predation	2	1	8	11
	Black bear	3	2	4	9
	Wolf	3	0	3	6
	Unknown predator	5	3	1	9
	Unknown cause	5	3	8	16
	Other	0	0	0	0

1.2 Elk calf survival and cause-specific mortality estimation

Summer, winter, and annual rates of survival

We used Cox-Proportional Hazards models (Lee 1992) and the survival package (Therneau 2018) to estimate and compare summer and winter survival rates in the pre-, during-, and post-treatment eras.

Estimates of both summer and winter survival were lowest prior to liberalized carnivore harvest management (pre-treatment era), highest during liberalized carnivore harvest management (during-treatment era), and at intermediate levels 4 years after liberalized carnivore harvest management (post-treatment era). Average summer survival rates were 0.46 (95% CI = 0.36-0.58) in the pre-treatment era, 0.67 (0.56-0.80) in the during-treatment era, and 0.57 (0.49-0.67) in the post-treatment era. Average winter survival rates were 0.74 (0.63-0.86) in the pre-treatment era, 0.93 (0.85-1.00) in the during treatment era, and 0.77 (0.71-0.85) in the post-treatment era.

To estimate rates of annual survival, we used the estimated summer and winter survival rates and multiplied the two seasonal rates together and obtained measures of uncertainty for each of the annual estimates using the delta method (Seber 1982).

Estimated annual rates of survival reflected summer and winter survival, such that annual calf survival was lowest in the pre-treatment era, highest in the during-treatment era, and at intermediate levels in the post-treatment era (Table 1.2). Annual estimates of survival were higher for female calves, but comparable between the East Fork and West Fork elk herds.

Table 1.2 *East Fork and West Fork herd annual calf survival rates and 95% confidence intervals, for the pre-treatment, during-treatment, and post-treatment eras at mean values of the mountain lion RSF covariate, specific to each sex, herd, and treatment era in the Bitterroot Valley, Montana, USA.*

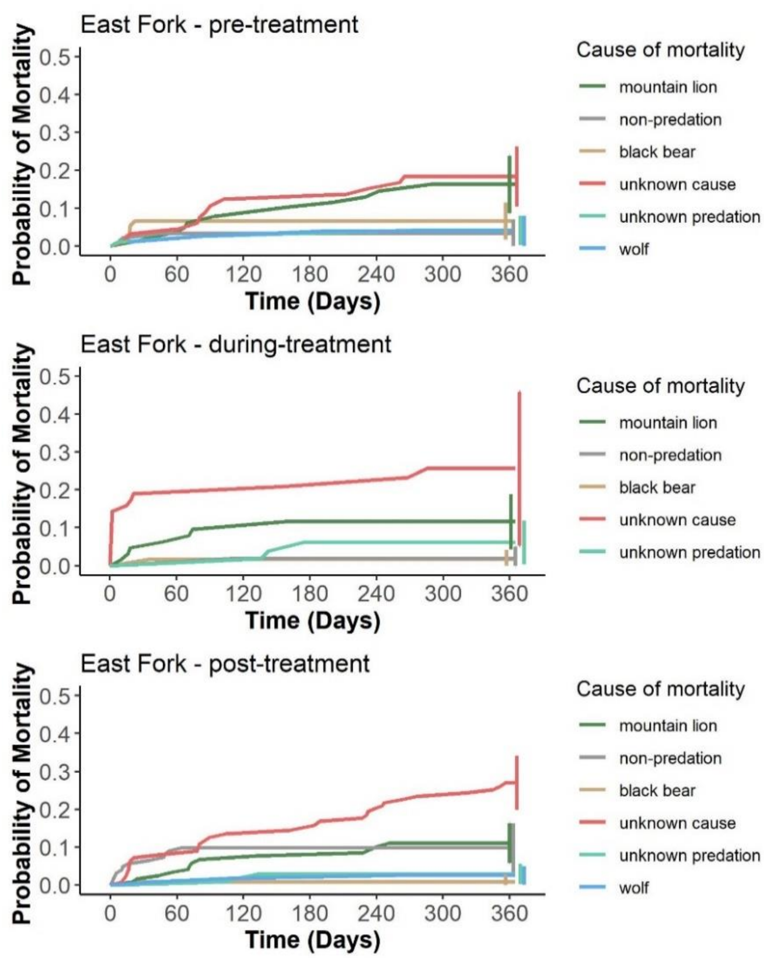
Herd	**Sex**	**Era**	**Annual Survival**
East Fork	Male	Pre	0.25 (0.13 - 0.42)
		During	0.52 (0.25 - 0.80)
		Post	0.34 (0.10 - 0.60)
East Fork	Female	Pre	0.37 (0.09 - 0.65)
		During	0.66 (0.46 - 0.87)
		Post	0.47 (0.32 - 0.62)
Herd	**Sex**	**Era**	**Survival - Mean**
West Fork	Male	Pre	0.24 (0.00 - 0.54)
		During	0.52 (0.26 - 0.78)
		Post	0.33 (0.10 - 0.56)
West Fork	Female	Pre	0.38 (0.17 - 0.58)
		During	0.65 (0.47 - 0.83)
		Post	0.46 (0.31 - 0.61)

1.3 Annual rates of cause-specific mortality

After classifying the cause of each calf mortality, we used cumulative incidence functions (CIFs) to quantify possible changes in calf mortality from each potential cause between the three treatment eras (Heisey and Patterson 2006, Eacker et al. 2016). To estimate CIFs for each potential cause of elk calf mortality, we used the R software platform (R Core Team 2018) and the *WILD1* package (Sargeant 2011). CIF estimates represented the cumulative probability of mortality from each potential cause over the first year (365 days) of a calf's lifetime.

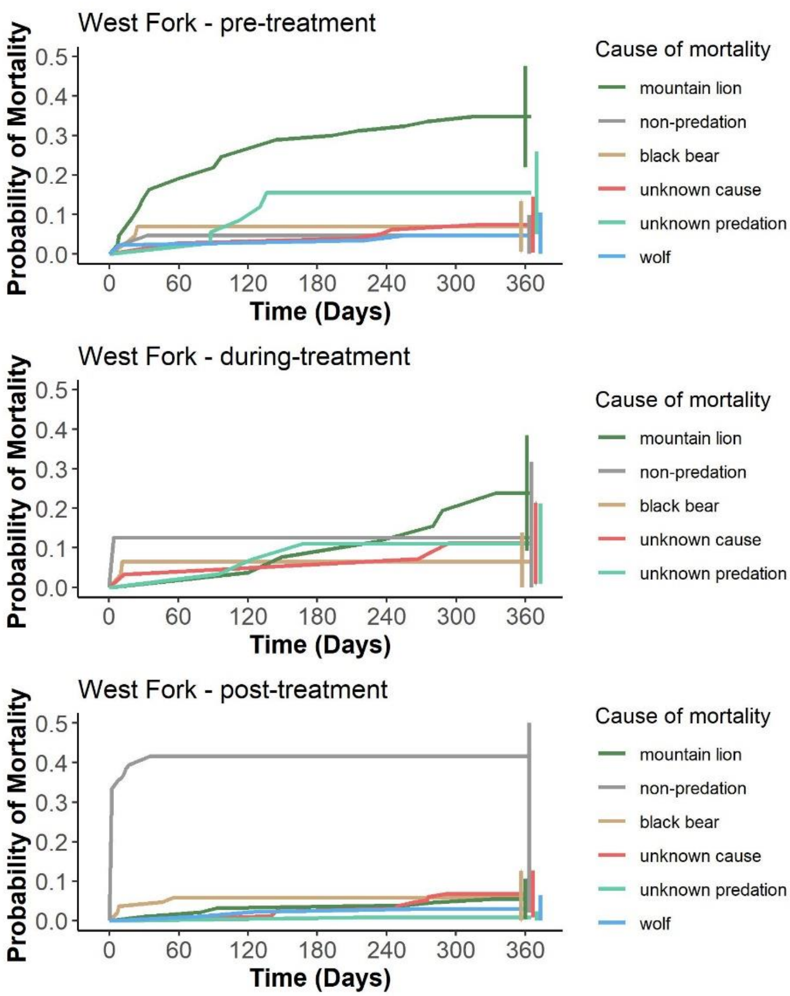
We estimated cause-specific mortality using data from 197 mortalities, 75 in the pre-treatment era, 35 in the during-treatment era, and 87 in the post-treatment era (Table 1.1). Estimated CIFs indicated that mountain lion predation was the largest known cause of mortality in the East Fork during all three treatment eras (Fig. 1.3), although cumulative mortality rates for non-predation and mountain lions were similar in the post-treatment era.

Figure 1.3. *Cumulative Incidence Functions (CIF) showing the cumulative probability of calf mortality (y-axis) from 0 to 365 days after parturition in the East Fork herd from mountain lions, wolves, black bears, non-predation, unknown predation, and unknown causes, by treatment era, in the upper Bitterroot Valley, Montana, USA, during pre-treatment, during-treatment, and post-treatment eras. Vertical bars show 95% confidence intervals for the cumulative probability of mortality from each cause at the end of one year.*



In the West Fork, estimated CIFs indicated that mountain lion predation was the largest known cause of mortality in both the pre- and during-treatment eras (Fig. 1.4), whereas non-predation was the greatest in the post-treatment era. The cumulative probability of non-predation mortality increased in the post-treatment era in both herds. With the exception of two calves that drowned, we were unable to assign the direct cause of non-predation mortality for the majority of elk calves that died from non-predation related causes. We found no evidence to suggest that any of the non-predation mortalities were related to disease, starvation, or abandonment. Elk calves are vulnerable to many potential sources of non-predation mortality during the neonatal period, many of which are hard to detect and predict. Annual probabilities of black bear and wolf predation were low in all three treatment eras for both herds. CIFs related to the annual probability of unknown cause mortality were high for both herds during all three treatment eras.

Figure 1.4. *Cumulative Incidence Functions (CIF) showing the cumulative probability of calf mortality (y-axis) from 0 to 365 days after parturition in the West Fork herd from mountain lions, wolves, black bears, non-predation, unknown predation, and unknown causes, by treatment era, in the upper Bitterroot Valley, Montana, USA, during pre-treatment, during-treatment, and post-treatment eras. Vertical bars show 95% confidence intervals for the cumulative probability of mortality from each cause at the end of one year.*



The rate of mortality for elk calves was highest during the first 90 days of the summer season and remained relatively constant across fall and winter. Mortality due to black bears and non-predation only occurred during the summer season, whereas mortality from mountain lions, wolves, and unknown causes occurred throughout the year. The CIF curves for unknown cause and unknown predator mortalities were not identical to any single source of known cause mortality. Thus, losses to unknown sources appear to come from a variety of mortality sources rather than to be dominated by a single cause. For example, in some cases, CIF curves related to unknown cause and unknown predator mortality were steep during the early summer months (i.e., similar to patterns black bear and non-predation mortality) but continued to increase through winter and the following spring (i.e., similar to CIFs for mountain lions and wolves).

Objective #2: Mountain lion population estimation

To assess the effects of mountain lion harvest management on mountain lion population abundance, we compared mountain lion abundance in a treatment and control area before and after 4-years of increasing mountain lion harvest quotas in the treatment area. During 2012 and 2103, we estimated pre-treatment mountain lion abundance in portions of the area managed for mountain lion reduction (Bitterroot study area) and the area managed for stability (Upper Clark Fork study area, Figure 2.1) in MFWP Region 2. During this period of the study, our objective was to use data collected during 2017-2018 to estimate mountain lion abundance in the Upper Clark Fork study area.

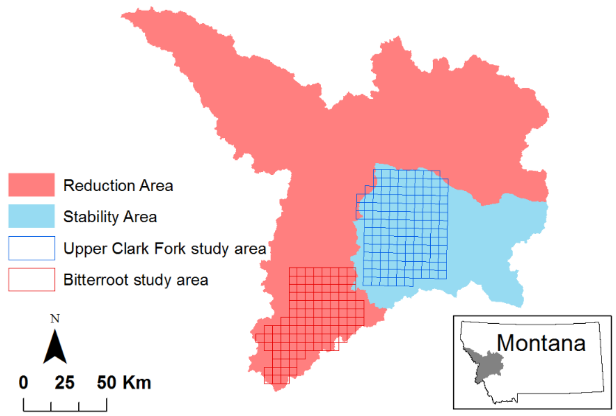


Figure 2.1 *Mountain lion harvest management goals in west-central Montana during 2012-2015 were to reduce mountain lion abundance by 30% across a portion of the region (shaded red) and maintain stable abundances across a portion of the region (shaded blue). The Bitterroot study area (red grid) was located in an area managed for a 30% reduction in mountain lion abundance and the Upper Clark Fork study area (blue grid) was located in an area managed for maintaining stable mountain lion abundance.*

2.1 Mountain lion harvest regulations and harvest

The Bitterroot (Ravalli County) study area includes hunting districts (HD) 250 and 270 and is within the area being managed for population reduction. In December 2012, median mountain lion density was estimated at 4.5 (95% CI = 2.9, 7.7) and 5.2 (95% CI = 3.4, 9.1 mountain lions/100km^2 in HD250 and 270 respectively (Proffitt et al. 2015*a*). The 2011 regulations included a subquota of 3 females in both hunting district (HD) 250 and 270, equating to 1.8 female licenses per 1,000km^2 (Table 2.1). In 2012 and 2013 regulations included 14 special licenses with subquotas of 7 females in both HD 250 and 270, equating to 4.2 female licenses per 1,000km^2. After 2013, female harvest levels were reduced. In 2016, regulations included subquotas of 3 and 5 females in HD 250 and 270 respectively, equating to 2.4 female licenses per 1,000km^2.

The Upper Clark Fork (Granite County) study area includes portions of HDs 210, 211, 212, 213, 214, 2015, 2016, and 217 and is located within the area being managed for stability. In December 2013, median lion density was estimated at 1.6 mountain lions per 100 km^2 (MFWP, unpublished data). During the last 10 years, regulations for these areas included female subquotas equating to 0 - 1.2 female licenses per 1,000km^2 (Table 2.2).

Table 2.1. *Mountain lion harvest quotas and harvest in the two hunting districts in the Bitterroot study area during 2001 - 2017. The Bitterroot study area is located within a watershed managed for mountain lion population reduction and included portions of HD 250 and 270.*

[1] During 2009-2011, there was no male subquota, only a female subquota and total harvest quota.
[2] There was a boundary change that expanded HD 270 and reduced the size of HD 250.

Year	*HD 270 Harvest Quota*			*HD 270 Harvest*		*HD 250 Harvest Quota*			*HD 250 Harvest*		*Female licenses per 1000 km^2*
	Female	Male	Total	Female	Male	Female	Male	Total	Female	Male	
2001	0	3		0	4	0	5		1	4	0.00
2002	0	3		0	3	0	5		0	5	0.00
2003	0	2		0	2	0	5		0	5	0.00
2004	0	1		0	1	0	2		0	3	0.00
2005	0	2		0	2	0	3		0	6	0.00
2006	0	3		0	5	0	4		0	3	0.00
2007	0	3		0	2	0	4		0	4	0.00
2008	0	3		0	1	0	4		0	1	0.00
2009	1	-	10[1]	1	4	1	-	10	0	3	0.60
2010	2	-	15	1	8	2	-	15	2	3	1.20
2011	3	-	20	3	6	3	-	20	3	4	1.80
2012	7	7		6	7	7	7		9	5	4.20
2013	6	4		7	4	6	4		4	6	3.60
2014[2]	4	5		5	5	3	5		1	3	2.10
2015	5	6		2	6	3	5		2	5	2.40
2016	5	6		6	5	3	5		2	2	2.40
2017	5	6		5	6	3	5		2	5	2.40

Table 2.2. *Mountain lion harvest quotas and harvest in the Clark Fork study area during 2001 - 2017. The Clark Fork study area is located within a watershed managed for maintaining stable mountain lion populations, and included portions of HD 210, 211/216, and 212/215/217.*

Year	*HD 210 Harvest Quota*			*HD 210 Harvest*		*HD 211/216 Harvest Quota*			*HD 211/216 Harvest*		*HD 212/215/217 Harvest Quota*			*HD 212/215/217 Harvest*	
	Female	Male	Total	Female	Male	Female	Male	Total	Female	Male	Female	Male	Total	Female	Male
2001				3	2	9	7		4	2	6	4		6	4
2002	1	4		1	1	2	4		2	1	6	4		6	4
2003	1	2		1	2	3	2		2	3	6	4		6	5
2004	1	5		1	2	3	2		3	2	6	4		1	3
2005	1	2		0	2	3	2		0	1	2	4		2	3
2006	0	2		0	2	0	2		0	0	0	4		0	3
2007	0	2		0	2	0	2		0	2	0	2		0	1
2008	0	2		0	1	0	2		0	2	0	2		0	0
2009	0	2		0	2	0	2		0	2	0	2		0	2
2010	2	-	4[1]	0	2	4	-	10	2	4	1	-	4	0	2
2011	2	-	4	2	2	4	-	10	1	4	1	-	4	0	3
2012	0	7		0	2	2	5		2	3	0	6		0	6
2013	0	3		0	5	3	5		2	2	0	6		0	7
2014	1	3		1	2	3	5		2	2	1	6		2	7
2015	1	3		1	3	3	5		1	4	1	6		1	6
2016	1	3		0	3	3	5		2	3	1	6		2	2
2017	1	3		0	3	3	5		0	2	1	6		1	6

Table 2.2 continued.
[3]During 2010-2011, there was no male subquota, only a female subquota and total harvest quota.

Year	*HD 213/214 Harvest Quota*			*HD 213/214 Harvest*		*Female licenses per 1000 km²*
	Female	Male	Total	Female	Male	
2001	1	1		0	0	2.33
2002	1	1		0	1	1.45
2003	1	1		1	0	1.60
2004	1	1		0	0	1.60
2005	0	1		0	0	0.87
2006	0	1		0	0	0.00
2007	0	1		0	0	0.00
2008	0	1		1	0	0.00
2009	0	1		0	1	0.00
2010	1	-	2	2	1	1.16
2011	1	-	2	1	2	1.16
2012	1	2		1	2	0.44
2013	1	2		2	2	0.58
2014	1	2		1	2	0.87
2015	0	2		0	3	0.73
2016	0	2		0	2	0.73
2017	0	2		0	2	0.73

2.2 Mountain lion population abundance in the Upper Clark Fork study area, 2017-2018

We used a spatially unstructured sampling design coupled to a spatially-explicit capture-recapture (SCR) model to estimate mountain lion abundance in the Clark Fork study area during December 1, 2017 – April 15, 2018 (Proffitt et al. 2015). The Clark Fork study area is located within the watershed that has been managed for stable mountain lion population abundance during 2012-2017. The Clark Fork watershed is located adjacent to the Bitterroot watershed that was managed for a moderate reduction in mountain lion population abundances during the same period. Our goal this year was to estimate Clark Fork population abundance following 4-years of stable mountain lion management.

Our approach used direct search effort by hound handlers and trackers in the study area to collect scat, hair and muscle samples for genetic analysis, allowing for individual mountain lion identification. The spatial locations of these samples were then used in a hierarchical model to estimate the relationship between mountain lion density and the underlying value of the statewide mountain lion resource selection function (Robinson et al. 2015). Additionally, we used spatial information from collared mountain lions to further inform sex-specific patterns of space use in the SCR model. This approach that integrates space use information from both recaptures and collars simultaneously reduces the bias and improves the precision of the resulting mountain lion abundance estimates.

During the 2017-2018 field season, approximately 11,000 km of search effort occurred from December to April (Figure 2.2). Genetic analysis of samples from the search effort identified 42 unique individuals (25 females and 17 males). Of those, 27 individuals were captured once, 10 were captured twice, 3 were captured 3 times and 2 were captured 5 times (Figure 2.3). Additionally, 9 mountain lions were fitted with GPS collars (6 females and 3 males) programmed to collect locations every 2-hours (Figure 2.4).

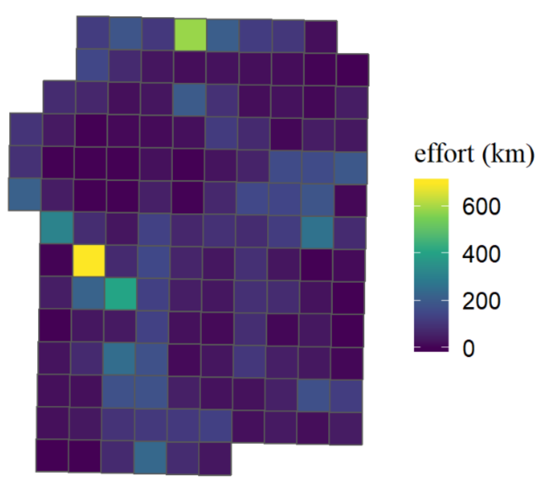


Figure 2.2 *The amount of search effort (km of search paths) in each of 136 trapping cells from December to April in the upper Clark Fork study area.*

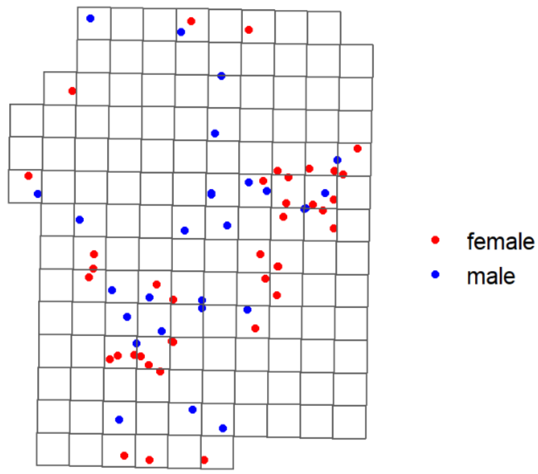


Figure 2.3 *Spatial locations of DNA samples used to estimate population abundance of mountain lions in the upper Clark Fork study area during winter 2017-2018.*

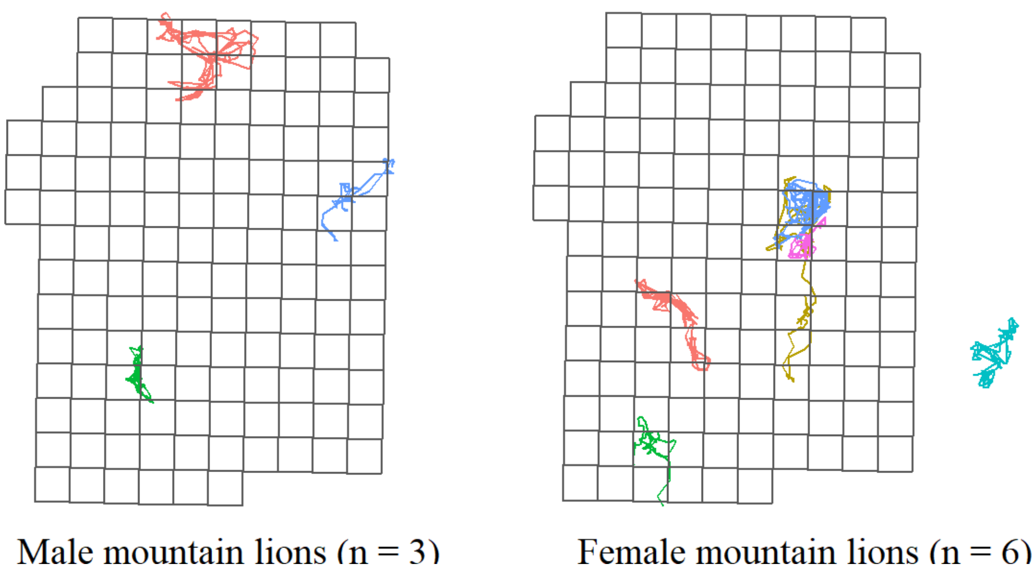


Figure 2.4 *Movements of collared male and female mountain lions in the in the upper Clark Fork study area during winter 2017-2018. This space use information was combined with spatial recapture information to estimate space use parameters in the spatial capture-recapture model estimating mountain lion population abundance.*

To estimate the abundance of mountain lions in the Clark Fork study area, we pooled information from the current 2017-2018 study with data collected during previous years of this project and developed a multi-strata spatial-capture model. The multi-strata SCR model incorporated spatial capture and recapture data from the Bitterroot and Clark Fork study areas across all years, and used information from collared individuals to help inform how animals use space. The multi-strata model combined the current dataset with data from the Bitterroot study area (2012 and 2016) and from the Clark Fork study area from 2013. This model allowed for sharing of information regarding baseline detection and space use parameters within study areas across years.

Based on this model, we estimated a median total abundance of mountain lions during 2017-2018 within the Clark Fork trapping grid of 72 lions (90% credible interval: 47 to 105), comprised of an estimated 28 males (18, 41) and 44 females (29, 64). Across the 3,396 km^2 Clark Fork trapping grid, this estimate corresponds to a density of approximately 2.1 mountain/100 km^2 (90% CI = 1.4/100 km^2, 3.1/100 km^2). This multi-strata model also resulted in minor changes to abundance estimates for the control area in 2013, and the treatment area in 2012 and 2016 (Table 2.3).

Table 2.3 *Female, male and total mountain lion population abundance estimates for the trapping grid in each area and year (median and 90% CI in parentheses) estimated from the multi-strata spatial capture-recapture model.*

Area	*Year*	Females	Males	Total
Bitterroot (treatment)	2012	81 (52, 117)	80 (52, 116)	161 (104, 233)
Bitterroot (treatment)	2016	82 (49, 124)	33 (20, 49)	115 (69, 173)
Clark Fork (control)	2013	33 (21, 49)	24 (16, 36)	57 (37, 85)
Clark Fork (control)	2017	44 (29, 64)	28 (18, 41)	72 (47, 105)

Objective #3: Evaluate the effects of wolf harvest management regulations on wolf harvest and population density.

Prior to 2011, wolves in the Bitterroot Valley were part of the experimental non-essential population that resulted from the reintroduction of wolves into the Central Idaho Experimental Area in 1995-96. In May 2011, wolves in Montana became subject to state management authority guided by the Montana Wolf Conservation and Management Plan. Across Montana, minimum wolf counts increased steadily until 2011. Since 2011, the statewide minimum counts and population estimates have been stable to declining, which is at least partially due to decreased effort to identify all wolves, and local population abundance varies annually with harvest management goals, management of livestock-wolf conflict, and other biological factors (Coltrane et al. 2016).

As part of the west-central Montana management to reduce carnivore densities, wolf harvest management prescriptions were implemented in the Bitterroot study area to reduce wolf population densities. Our objectives are to evaluate the effects of wolf harvest management regulations on realized wolf harvest and population abundance in the south Bitterroot study area.

3.1 Wolf harvest regulations and harvest

Between 2008 and 2011, wolves in Montana were delisted, relisted, and then delisted again (Hanauska-Brown et al. 2011). This process resulted in a Montana wolf hunting season in 2009, no hunting season in 2010, and then wolf hunting seasons from 2011 through the present. Since MFWP most recently regained wolf management authority in 2011, wolf harvest limits and hunting season dates have been liberalized, and the use of specific trapping methods has been approved. Since 2011, there are no wolf harvest limits for HD 270 or 250 areas. Harvest regulations are based on combined hunting and trapping bag limits of wolves per person. In 2012, wolf harvest regulations limited each person to harvesting a maximum of 3 wolves, with no more than 1 taken during the rifle season. In 2013 until present, wolf harvest regulations limited each person to harvesting a maximum of 5 wolves.

All hunters and trappers are required to report all harvested wolves to MFWP. We used hunter and trapper reports to track the number of wolves harvested annually from mandatory reporting records (Table 2.3).

Table 2.3 *The annual reported harvest of wolves in the in the HD 270 and HD 250 area of the south Bitterroot study area during 2008–2017.*

Year	HD 270 Harvest	HD 250 Harvest
2008	0	0
2009	2	3
2010	0	0
2011	5	6
2012	5	8
2013	6	4
2014	3	1
2015	2	2
2015	2	2
2016	15	4
2017	9	1

3.2 Wolf population estimation

MFWP uses a combination of radio-collaring efforts, direct observational counts, remote cameras, and track surveys to annually track the wolf population, to document pack size and breeding pair status of known packs, and to determine pack territories in our study area. Ground and aerial tracking occurs 1-2 times per month to locate VHF and GPS collared animals and count the number of wolves travelling together. Additional information on sightings, breeding activity, mortalities, and human-wolf conflicts is collected throughout the year. This information is used to estimate the minimum count of wolves per hunting district on December 31st of each year (Coltrane et al. 2016).

In 2000, MFWP counted a minimum of 7 wolves in the entire Bitterroot Valley, and the minimum count increased to a high of 74 in 2011. In 2011, there was a minimum of 28 wolves in the West Fork (1.95wolves/100km^2) and 8 wolves in the East Fork (0.47 wolves/100km^2) of the south Bitterroot study area (Table 2.4).

Table 2.4 *The estimated minimum count of wolves in the HD 270 and HD 250 area of the south Bitterroot study area during 2001-2017.*

[1] There was a boundary change that expanded HD 270 and reduced the size of HD 250.Year	HD 270 Minimum count	HD 270 Minimum number per 100 km^2	HD 250 Minimum count	HD 250 Minimum number per 100 km^2
2001	2	0.12	5	0.35
2002	5	0.29	5	0.35
2003	Not available	Not available	4	0.28
2004	Not available	Not available	6	0.42
2005	Not available	Not available	11	0.77
2006	10	0.58	11	0.77
2007	17	0.99	14	0.97
2008	15	0.87	19	1.32
2009	13	0.76	24	1.67
2010	20	1.16	30	2.09
2011	8	0.47	28	1.95
2012	10	0.58	23	1.60
2013	12	0.70	16	1.11
2014[1]	27	1.57	7	0.49
2015	19	1.11	7	0.49
2016	20	1.16	9	0.63
2017	19	1.11	14	0.97

Acknowledgements

We thank the landowners that have allowed access for fieldwork and provided logistical support. We also thank the many Fish, Wildlife and Parks staff, Montana State University staff, and other volunteers for their hard work and participation in the elk calf capture. We thank project hound handlers J. Burdett, R. Castle, C. Dunlap, B. Dunne, J. Knight, E. Hampson, C. Hensen, L. Hensen, B. Weisner, B. Wohlers for their work tracking and sampling mountain lions. We thank project field technicians G. Geldersma, A. Kornak, E. Moran, B. Turnock, and C. White for their dedicated work on this project. We thank the pilots that have safely conducted elk capture and telemetry flights including N. Cadwell, B. Malo, R. Swisher, and T. Throop. Funding was provided by revenues from the sale of Montana hunting and fishing licenses and matching Federal Aid in Wildlife Restoration grants to Montana Fish, Wildlife and Parks, and by the Rocky Mountain Elk Foundation.

Literature Cited

Andren, H. and O. Liberg. 2015. Large impact of Eurasian lynx predation on roe deer population dynamics. PLoS One 10:e0120570.

Barber-Meyer, S. M., L. D. Mech, and P. J. White. 2008. Elk calf survival and mortality following wolf restoration to Yellowstone National Park. Wildlife Monographs 169:1-30.

Biek, R., N. Akamine, M. K. Schwartz, T. K. Ruth, K. M. Murphy, and M. Poss. 2006. Genetic consequences of sex-biased dispersal in a solitary carnivore: Yellowstone cougars. Biology Letters 2:312-315.

Bunnell, S. D., Wolfe, M. L., Brunson, M. W. & Potter, D. R. (2002). Recreational use of elk. Pages 701-748 in North American elk. Ecology and Management. Smithsonian Institution Press. Washington, D.C. USA.

Coltrane, J., J. Gude, B. Inman, N. Lance, K. Laudon, A. Messer, A. Nelson, T. Parks, M. Ross, T. Smucker, J. Steuber, and J. Vore. 2016. Montana gray wolf conservation and management 2015 Annual Report. Montana Fish, Wildlife & Parks. Helena, MT, USA.

Cook, R. C., J. G. Cook, D. J. Vales, B. K. Johnson, S. M. Mccorquodale, L. A. Shipley, R. A. Riggs, et al. 2013. Regional and seasonal patterns of nutritional condition and reproduction in elk. Wildlife Monographs 184:1-45.

DeCesare, N. J., M. Hebblewhite, M. Bradley, K. G. Smith, D. Hervieux, and L. Neufeld. 2012. Estimating Ungulate recruitment and growth rates using age ratios. The Journal of Wildlife Management 76:144-153.

Eacker, D. R., M. Hebblewhite, K. M. Proffitt, B. S. Jimenez, M. S. Mitchell, and H. S. Robinson. 2016. Annual elk calf survival in a multiple carnivore system. The Journal of Wildlife Management 80:1345-1359.

Gaillard, J.M., M. Festa-Bianchet, and N. G. Yoccoz. 1998. Population dynamics of large herbivores: Variable recruitment with constant adult survival. Trends in Ecology and Evolution 13:58-63.

Gaillard, J.-M., M. Festa-Bianchet, N. G. Yoccoz, A. Loison, and C. Toigo. 2000. Temporal variation in fitness components and population dynamics of large herbivores. Annual Review of Ecology and Systematics. 367:393-31.

Gardner, B., J. Reppucci, M. Lucherini, and J. A. Royle. 2010. Spatially explicit inference for open populations: estimating demographic parameters from camera-trap studies. Ecology 91:3376-3383.

Garrott, R. A., L. L. Eberhardt, P. J. White, and J. Rotella. 2003. Climate-induced variation in vital rates of an unharvested large-herbivore population. Canadian Journal of Zoology 81:33-45.

Garrott, R. A., P. J. White, and J. J. Rotella. 2008. The Madison headwaters elk herd: transitioning from bottom-up regulation to top-down limitation. Pages 489-518 in R. A. Garrott, P. J. White, and F. G. R. Watson, editors. The ecology of large mammals in central Yellowstone: 16 years of integrated studies. Academic Press, New York.

Haggerty, J. H., and W. R. Travis. 2006. Out of administrative control: absentee owners, resident elk and the shifting nature of wildlife management in southwestern Montana. Geoforum 37:816-830.

Harris, N.C., M. J. Kauffman, and L. S. Mills. 2008. Inferences about ungulate population dynamics derived from age ratios. The Journal of Wildlife Management 72:1143-1151.

Hanauska-Brown, L., L. Bradley, J. Gude, N. Lance. Montana gray wolf conservation and management 2011 annual report. 2011. Montana Fish, Wildlife & Parks. Helena, MT, USA.

Hebblewhite, M., D. H. Pletscher, and P. C. Paquet. 2002. Elk population dynamics in areas with and without predation by recolonizing wolves in Banff National Park, Alberta. Canadian Journal of Zoology 80:789-799.

Heisey, D. M., and B. R. Patterson. 2006. A review of methods to estimate cause-specific mortality in presence of competing Risks. The Journal of Wildlife Management 70:1544-1555.

Kauffman, M. J., J. F. Brodie, and E. S. Jules. 2010. Are wolves saving Yellowstone's aspen? A landscape-level test of a behaviorally mediated trophic cascade. Ecology 91:2742-2755.

Lee, J., C. Yoshizawa, L. Wilkens, and H. P. Lee. 1992. Covariance adjustment of survival curves based on Cox′s proportional hazards regression model. Bioinformatics 8:23-27.

Messier, F. 1994. Ungulate population models with predation: a case study with the North American Moose. Ecology 75:478-488.

Montana Department of Fish, Wildlife and Parks. 2004. Montana statewide elk management plan. Montana Fish, Wildlife and Parks. Helena, MT, USA.

Nelson, L.J. and J. M. Peek. 1982. Effect of survival and fecundity on rate of increase of elk. Journal of Wildlife Management. 46:535-540.

Proffitt, K. M., B. Jimenez, C. Jourdonnais, J. A. Gude, M. Thompson, M. Hebblewhite, and D. R. Eacker. 2015*a*. Evaluating bottom-up and top-down effects on elk survival and recruitment in the southern Bitterroot Valley, Montana. Final Report, Montana Fish Wildlife and Parks, Helena, USA.

Proffitt, K. M., J. F. Goldberg, M. Hebblewhite, R. Russell, B. S. Jimenez, H. S. Robinson, K. Pilgrim, M. Schwartz. 2015*b.* Integrating resource selection into spatial capture-recapture models for large carnivores. Ecosphere. 6:1-15

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Raithel, J. D. 2005. Impact of calf survival on elk population dynamics in west-central Montana. The University of Montana. <http://jhraithel.com/files/.LRaithel_UMT MS Thesis_May 22 2005 FINAL.pdf>. Accessed 14 Jan 2015.

Robinson, H. S., et al. 2015. Linking resource selection and mortality modeling for population estimation of mountain lions in Montana. Ecological Modelling 312: 11–25.

Royle, J. A., K. U. Karanth, A. M. Gopalaswamy, and N. S. Kumar. 2009. Bayesian inference in camera trapping studies for a class of spatial capture-recapture models. Ecology 90:3233-3244.

Russell, R. E., J. A. Royle, R. Desimone, M. K. Schwartz, V. L. Edwards, K. P. Pilgrim, and K. S. McKelvey. 2012. Estimating abundance of mountain lions from unstructured spatial sampling. Journal of Wildlife Management 76:1551-1561.

Sargeant, G. R., 2011. Tools for wildlife research and management. R package version 1.09.

Seber, G. A, 1982. The estimation of animal abundance and related parameters. Macmillan Publishing Company, London, United Kingdom.

Sutherland, C., Royle, A., and D. Linden. 2017. oSCR: Multi-session sex-structured spatial Capture-recapture Models. R package version 0.40.1.

Therneau, T. M., 2018. Survival analysis. R package version 2.43-3

U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. 2011 national survey of fishing, hunting, and wildlife associated recreation. U.S. Fish and Wildlife Service, Shepherdstown, WV, USA.